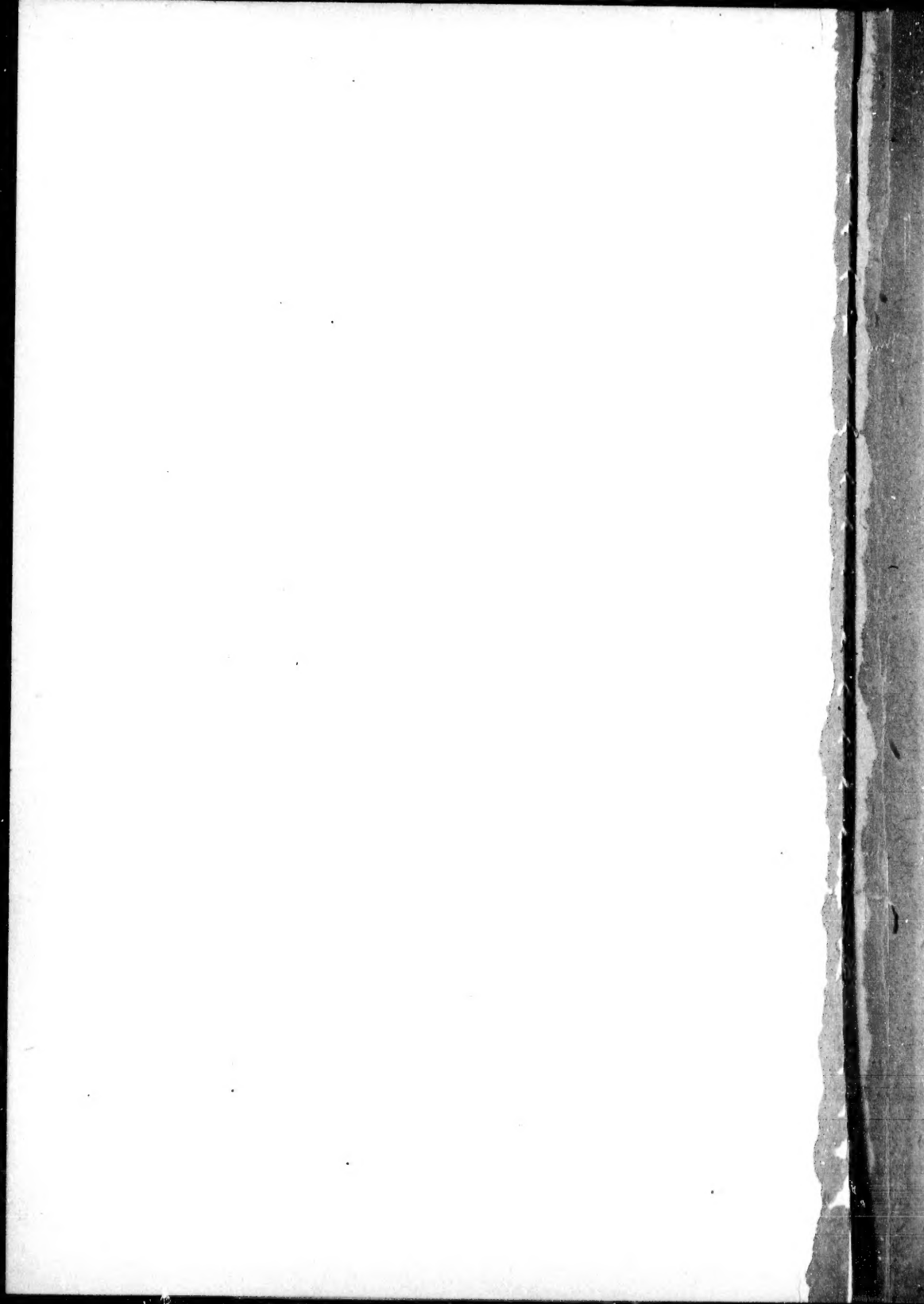




*with the author's
Crawlin cuts*

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 5, PP. 117-146

GEOLOGICAL NOTES ON SOME OF THE COASTS AND
ISLANDS OF BERING SEA AND VICINITY

BY

GEORGE M. DAWSON

ASSISTANT DIRECTOR OF THE GEOLOGICAL SURVEY OF CANADA



ROCHESTER
PUBLISHED BY THE SOCIETY
FEBRUARY, 1894

189A
(39)

GEOLOGICAL NOTES ON SOME OF THE COASTS AND
ISLANDS OF BERING SEA AND VICINITY

BY GEORGE M. DAWSON

ASSISTANT DIRECTOR OF THE GEOLOGICAL SURVEY OF CANADA

(Read before the Society December 27, 1893)

CONTENTS

	Page
Introduction.....	117
Aleutian Islands.....	119
Akutan Island.....	119
Unalaska Island.....	120
Atka Island.....	120
Great Sitkin Island.....	121
Buldir Island.....	121
Semichi Islands.....	121
Attu Island.....	122
Commander Islands.....	123
Bering Island.....	124
Copper Island.....	126
Kamchatka.....	127
Pribilof Islands.....	130
Nunivak Island.....	133
Cape Vancouver.....	134
Saint Matthew, Hall and Pinnacle Islands.....	135
Saint Lawrence Island.....	138
Plover Bay.....	140
General Remarks.....	143

INTRODUCTION.

The notes here presented are those made during an extended cruise in the Bering sea region during the summer of 1891. The writer was at the time more particularly engaged in the investigation of matters connected with the fur-seal, as one of the British commissioners appointed for that purpose, but his somewhat prolonged familiarity with the geological features of British Columbia and adjacent parts of northwestern Canada caused him to feel a special interest in the corresponding features of the

various places visited. The time available for observations ashore was usually very limited, and thus, but for the fact that so little is yet known respecting the geology of the whole region, such notes as it was possible to make would possess very little inherent value. As it is, they may be accepted as a slight contribution to our knowledge of a portion of the globe of which but a few limited spots have yet come under the observation of any trained geologist.

Dr W. H. Dall has lately collected in a single work a précis of nearly all the authentic data relating to the American shores and islands of Bering sea.* This work is devoted specially to the Neocene formations, but these include a great part of those known to occur, and references are besides given in it to various older formations. Allusion is frequently made to this work of Dr Dall's in the sequel, and in so far as they cover



FIGURE 1.—Map of Coasts and Islands of Bering Sea.

the same ground the notes here set down may be regarded as merely supplementary to those he has published either as the result of his own observations or in the form of extracts from older works. Thus in what follows respecting the Aleutian islands, it will be found that only those touched at or seen by the writer are mentioned, and, generally speaking, that greater attention is given to places about which the known facts are particularly scanty or altogether wanting, and to those more general physiographic features of the land to which the attention of the earlier explorers was not directed.

Mr W. F. Ferrier, lithologist to the Geological Survey of Canada, has been so kind as to look over the rock specimens brought back, and in some cases has examined them microscopically in thin sections for the purpose of their determination.

*Bull. U. S. Geological Survey, no. 84, 1892, p. 234 et seq.

ALEUTIAN ISLANDS.

Akutan Island.—The south side of this island was the first part of the Aleutian chain sighted by us in approaching Bering sea. It is characterized by rugged and bold cliffs, broken into stacks and pinnacles at the points, but between retiring into coves and bays, from some of which rather wide valleys run inland. The varied and often strongly contrasting coloring of the weathered rocks in these cliffs, together with the absolute treelessness of the land and the vivid green of the sward and herbage with which it is covered wherever not too rocky or too elevated for any growth, were the most striking features. These, however, are almost equally found in all the islands of the Aleutian chain.

Steep and irregular hills and ridges rising from the shores culminate in the central part of the island in mountains sufficiently high to carry

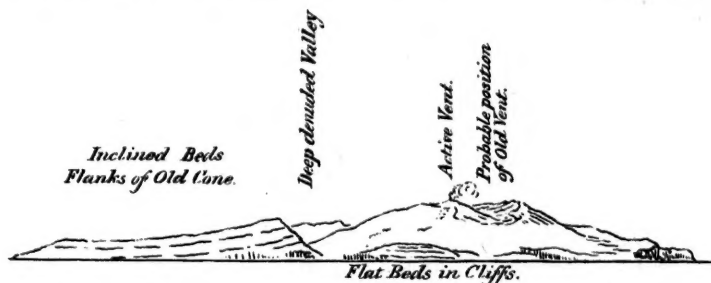


FIGURE 2.—Diagram illustrating the Structure of the northern Part of Akutan Island.

much snow in these latitudes the year round. The north side of this island was afterward seen under favorable conditions of weather, and the island as a whole appears to represent the denuded remnants of a single great volcanic center. The original focus of eruption seems to have been situated to the west of the middle of the island. Somewhat nearer the actual center of the island a little cloud of steam still issues from one of the higher points, and occasional small eruptions have been noted.*

The eastern portion of the island shows part of the lower slope of the original great volcanic cone, the beds flattening out gradually to the eastward in conformity with the decreasing slope of the surface.

The antiquity of the volcanic action to which the island as a whole owes its origin, is shown by the amount of the subsequent effect of denudation upon it. The deep valleys have evidently been cut out by ordinary subaërial erosion during a prolonged period of waste, and many of the

* Alaska and its Resources: Dall, pp. 467, 470.

lower ridges and hills owe their present forms entirely to such action. The peripheral parts of the island have during the same period been much reduced and cut back by the sea.

The cliffs along the south shore and those about the middle of the north shore display bedding, which in the planes of section appears nearly horizontal. The individual beds are for the most part thick, and some of them show a pronounced basaltic structure.

Unalaska Island.—Respecting the island of Unalaska little can be added to the notes lately brought together by Dr Dall.* A good view was obtained of that part of the north coast between Makushin and Captain's bays, behind which rises Makushin volcano, the highest mountain (5,474 feet) on the island. The upper parts of this mountain and the high ridges about it were deeply covered with snow in August, and small, irregular glacier masses, more or less crevassed, were observed here and there.

Makushin is not a typical volcanic cone, but an irregular, lumpy mountain mass with some rather bold spurs and crests even about its upper parts, which seem to evidence considerable waste by denudation since the latest important eruptions. A cloud of white steam still, however, hangs about its summit. The natural processes of waste have not acted sufficiently long upon this island to produce rounded forms or light slopes. The hills are generally sharp edged, peaked and bold, but often covered with herbage nearly to their tops.

The shore-cliffs, from abreast of Makushin to Captain's harbor, show horizontal or slightly inclined bedding, which is rather too fine and uniform to be explained as that of superposed lava flows. The beds exposed probably consist of scoria or volcanic ash deposited under water. Dall notes the occurrence of marine Miocene deposits in Makushin bay.†

The slopes and hills about Captain's harbor were all closely scanned for evidence of old beachlines, but none were seen. There appears to have been no notable upward movement of this land since the denudation which produced its present form took place. The little flat about the village of Unalaska is composed of gravel covered with black soil, and is about twenty feet above high-water mark. Its occurrence might almost be explained as a beach deposit at the present storm level, but it more probably indicates a very slight rise of the land.

Atka Island.—A call was made at Nazan bay, on the east side of Atka island. This island, with others near it which were more or less imperfectly seen, appears to be practically entirely composed of volcanic rocks. Some interesting notes on Atka are given by Dall in the publication

* Op. cit., p. 242.

† Op. cit., p. 243. In addition to the volcanic rocks of various kinds, Dall mentions the occurrence of granite or syenite [gabbro ?] in the interior of this island. Op. cit., pp. 233, 242.

already quoted (pages 243-244), from which it appears that in Karovinski bay, on the west side of the island, pieces of fossil wood, sometimes silicified, as well as marine Miocene fossils in tuffaceous volcanic deposits, are found. The little islands in Nazan bay and the low projecting points about it have a basaltic appearance and rather irregular columnar structure. The rock showing on the beach, at the village, is a greenish gray, fine grained material, very hard and in places containing many grains of iron-pyrites, probably elastic and apparently a diabase, though not microscopically determined. It is also traversed by small drusy veins of quartz, and large loose masses of quartz were found which had evidently not travelled far.

In a small brook, which has cut out a little ravine near the village, a considerable depth of superficial earthy material is exposed. This exhibits a certain amount of stratification parallel to the slope of the ground. It is brownish or reddish brown in color, and appeared to be composed of volcanic detritus, which has either been deposited in the sea when the land was at a somewhat lower level, or perhaps more probably merely washed down the slopes while in an incoherent and fresh state. Material of the same kind was recognized elsewhere on this and other islands of the Aleutian chain, sometimes in rather notable quantity.

No indications of old terrace levels were observed about Nazan bay, but around the base of the mountain which forms a projecting point to the north of the entrance of the bay, three or more successive, indistinct terrace-like markings occur, the highest being at an elevation of about 1,000 feet above the present sea level. These markings may represent old beachlines impressed in soft material, but from their indefinite character this remains uncertain.

Great Sitkin Island.—After passing Atka island a fine general view of Great Sitkin island was obtained. This evidently consists of a single large volcanic cone, which, according to the charts, is still 5,033 feet high. Its upper portion was heavily covered with snow.

Buldir Island.—Buldir island was passed sufficiently near to enable it to be well seen. Its eastern end is most elevated, and high cliffs there show a series of flows or beds of volcanic material, dipping rather steeply westward. The angle of dip gradually diminishes and the stratification becomes horizontal at the west end of the island, the general height of the surface decreasing in a corresponding degree. The whole island clearly represents the residual portion of an originally symmetrical volcanic mountain, the greater part of which has been cut away by the sea.

Semichi Islands.—The Semichi islands form a narrow chain, broken by two small gaps, and about fourteen miles in total length. They are un-

usually low and flat, the highest point, at the western end, being, according to the chart, about 800 feet. The islands slope down to the southward with nearly uniform grassy surfaces.

Attu Island.—This is the westernmost island of the Aleutian chain. It appears to be throughout mountainous, and, in its general contour, with steep, grassy elevations, closely set, is not unlike most of the larger islands of the chain. Its highest point, according to the chart, is 3,084 feet.

My observations were confined to the vicinity of Chichagof harbor, on the north side of the island. At the east end of the gravelly beach at the bottom of the harbor, hard, greenish gray rocks occur, possibly diabase in composition, but too fine grained for macroscopic determination. These are in some places distinctly bedded and probably clastic, the dip being north 65° west (magnetic), at an angle of 45° . Similar rocks, with a similar dip, appear on the opposite side of the harbor at the west end of the same gravel-beach, and were again found at the summit of the mountain or high ridge on the east side. The rocks of Gibson island, off the mouth of the harbor, were observed to be bedded with such unusual regularity that this island was specially visited. They proved to consist for the most part of much altered and indurated volcanic materials, with purplish, greenish and gray colors. Perhaps the most abundant material is a medium grained rock, which in some specimens is evidently an eruptive, in others probably clastic, and very possibly a diabase in composition, but fine grained clastic felspathic rocks also occur, which pass into a black compact material which is apparently a true argillite. Though sought for, no fossil remains of any kind could be found. The dip is here north 30° east (magnetic), at an angle of 40° .

The rocks seen in the harbor closely resemble those noted in Nazan bay, Atka island. The general lithological character and degree of alteration of the rocks of this part of Attu island resembles that of some of the Mesozoic rocks of British Columbia, particularly parts of the Triassic series as represented there, and though such a criterion is of very limited value, Dall may not improbably be correct in his conjecture that they are of Mesozoic age.* In any case, the high angles at which these rocks lie and the amount of alteration and denudation which they have suffered show that beds much older than those referable to modern or even late Tertiary volcanic action are included in the composition of this part of the Aleutian chain.

Dr Dall states that Attu is destitute of modern volcanic rocks, and my observations, so far as they go, are to the same effect. Even in the gravel

*Op. cit., p. 344. The occurrence of Triassic rocks in the peninsula of Alaska is indicated by specimens from that peninsula shown to me by Mr R. Neumann, of Unalaska. These consist of the Monotis-bearing argillite of that formation.

of the beaches such rocks appear to be wanting. The pebbles consist chiefly of materials like those observed to occur locally, but a considerable number of gray granitoid fragments were also observed along the shores, of which the origin is uncertain. It is noteworthy that though this island thus appears to be composed of older rocks than most of the Aleutians, its topographic forms are not dissimilar from those of the other islands. No distinguishing features are, for example, apparent between the hills surrounding Chichagof harbor and those near Captain's harbor in Unalaska.

About Chichagof harbor there are some well marked old seacliffs rising behind gravelly flats of twenty or thirty feet in height, and such as to indicate an elevation of the land by that amount since their formation. On the slopes of the ridge on the west side of the harbor, several faintly impressed horizontal lines also appear, the highest being about 300 feet above the sea. They seem to represent incipient terraces, and, if so, must indicate a somewhat rapid elevation of the land, such as to prevent any long continued marine action at any particular level.

COMMANDER ISLANDS.

Bering and Copper islands, with a few adjacent rocks and reefs of no importance, form the Komandorski or Commander group appurtenant to Russia and subsidiary to the government of the Amur. The two islands are parallel in trend, lying in northwest by southeast bearings. They are separated at their nearest points by a distance of 26 nautical miles. Copper island, which lies farthest to the eastward, is divided by 190 miles of deep ocean from Attu, the easternmost of the Aleutian chain, while Bering island is distant some 95 miles from the nearest part of the peninsula of Kamchatka. The high volcanic mountains of the peninsula may in clear weather be seen from Bering island, but the latter is probably never under any circumstances visible from the mainland. In view of the fact that the Aleutian islands were, when discovered, rather thickly inhabited, and that evidences exist on them of inhabitants long antecedent to historic times for the region,* it is somewhat remarkable that the Commander islands appear never to have been visited by man previous to their discovery by the Russians in 1741. The climate of these islands is humid and cool, insuring a luxuriant growth of grasses and herbaceous plants of various species wherever there is sufficient soil, but though less rigorous than that of the lands in similar latitudes on the eastern side of Bering sea, no trees or shrubs are anywhere found upon them.

* Dall in Contributions to North American Ethnology, vol. I.

Bering Island.—Bering island is about 50 miles in extreme length, with a width of nearly 20 miles at its northern and wider end. From this it narrows gradually, but irregularly, to cape Maniti, its southeastern extremity. The northern half of the island is low, with a rolling or nearly flat surface, much of which is described as consisting of "tundra" land. It includes one large lake, which discharges on the north shore. The southern half is higher, and appears, as seen from the sea, to consist of a mass of rounded hills, varying in height from several hundred to perhaps 1,000 feet. There are no harbors about the island, but a fair anchorage, with off-shore winds, may be found in a bay at Nikolski, on the west coast of the island, about ten miles from its northern end. The only permanent settlement, with the headquarters of the Russian government of the islands, is situated at this place.

The shores of the higher southern portion of the island are generally bordered by cliffs or steep scarped banks, with narrow and V-shaped valleys breaking through them to the sea.

On the east side of cape Maniti, and for some miles northward, regularly stratified rocks in rather thin beds of pale brownish colors were observed, dipping regularly northward at an angle of about 15°. Farther to the northwestward, along the same eastern coast, at cape Tolstoi (thirteen miles from cape Maniti) paler fawn-colored or cream-colored beds were seen, dipping away from the shore at low angles. They are crumbling and incoherent in character, and produce long slopes of débris in some places between the bluffs and the sea. Similar rocks apparently continue from cape Tolstoi to Stareya bay, at a further distance of nineteen miles, but the cliffs become lower and the scarped banks are less steep.

A landing was effected at Stareya bay, when it was found that the scarped slopes, which often resemble sand from a distance and are so described in sailing directions, are in reality composed of angular and rubbly fragments of whitish, yellowish and gray argillites or shales, with crumbling sandstones and argillaceous, fine grained gray limestones. All these rocks are well bedded, and on some surfaces small carbonaceous plant fragments were observed, though none of these were determinable. The material of the beach is composed almost entirely of the débris of similar rocks, and it is probable that the whole northeastern coast of the island, at least this far, consists of moderately indurated sediments of Tertiary age, regularly bedded and present in considerable or great thickness. The browner beds of the vicinity of cape Maniti may, however, be tuffaceous volcanic material. While it is not improbable that basaltic or other volcanic rocks may also occur, as some such were found upon the shore, they were not actually seen in place. No

crystalline or other evidently foreign rocks were found upon the beaches. The soil in the valleys and on the lower slopes of the hills is a reddish, fine grained material, doubtless formed by the disintegration of the rocks above described.

No satisfactory general views of the coastline of the northern and lower part of Bering island were obtained on account of foggy weather. A landing was, however, made on the north shore at cape Yushin, where the "north rookery" is situated. The shore is here rocky, and wide, low reefs run out from it, entirely composed of volcanic rocks. One of these is a dark brown melaphyre, containing plagioclase, augite and olivine crystals, with some magnetite, embedded in a groundmass of the same constituents. There is also a fragmental rock of somewhat peculiar appearance, which seems not to be a true agglomerate, but an eruptive material charged with fragments of dissimilar rocks. The basis is somewhat amygdaloidal, and may very probably have the same composition as the rock first noted. Well formed pyroxene crystals are abundant in some parts of the mass. The rocks are much shattered, and it was not easy to determine the precise relations of the two varieties here associated. No trace of sedimentary rocks like those of Stareya was seen.

At Nikolski, on the west side of the island, the point south of the little bay is composed of hard, fine grained, gray, augite-porphyrity, composed of plagioclase, augite, and a light brown biotite, considerably altered to chlorite, apatite and magnetite. It is homogeneous in texture and apparently massive. Here and there this rock is curiously spotted with flesh-colored chalcedony, which occurs in it in small kernels not distinctly amygdaloidal. The relation which this rock may bear to the stratified sediments of other parts of the island remains uncertain, as no sedimentary rocks were seen here. Basaltic rocks are, however, probably abundant in the northern part of the island, for fragments of such rocks are common on the beaches.

The shores about Nikolski in some places show a well marked low terrace, at twenty to thirty feet above high-water mark, which evidently indicates an elevation of about that amount, as there is a second still lower flat just above the actual beach, which may be accounted for by the accumulation of storm-wash under the present conditions or very nearly so. This lower flat is no doubt that in which the *Rhytina* bones were found to be most abundant by Nordenskjöld. With these exceptions no terracing was observed in Bering island. According to Mr N. Grebnitsky, the governor of the Commander islands, some fossil shells and plants have been found in the rocks of Bering island, which, on transmission by him to Saint Petersburg, were referred to the Miocene Tertiary. Lignite is also found on the island, but in inconsiderable

quantity. Nordenskjöld gives some general notes on Bering island, and quotes a statement made to him by Mr Grebnitsky of a character similar to the above.*

To the south of Nikolski the western shore of Bering island was not seen.

Copper Island.—Copper or Medni island is about thirty miles in length, with a greatest width of about five miles, to the south of the middle of the island. It forms a single mountainous ridge, of which the highest parts probably attain an elevation of 3,000 feet, and is much bolder in outline than Bering island. Its surface is exceedingly irregular, and comprises very little flat land of any kind, while its shore is often bordered by high and rugged seacliffs, particularly along the southeastern side. The shoreline of this side is sinuous, while that of the northeastern side is deeply indented by several considerable bays, but affords no good harbors for large vessels. There are three small settlements on the northeast coast—Glinka, Karabelny and Preobajenski—the last named being the most northern and the only one continuously occupied during the winter months.

The island appears to be almost entirely composed of volcanic rocks of some antiquity. No volcanic cones or craters were observed, but, on the contrary, the existing relief is evidently the result of ordinary denudation. The slopes are generally steep and are sometimes surmounted by rocky crests, but are usually more or less completely grass-covered from base to summit. The hills in their form and general appearance much resemble those of the higher parts of Saint Matthew island.

Copper island was crossed near its southeastern end from Glinka (Pestchanni of some charts). At Glinka the rocks seem to have a general southeasterly dip, and both here and on the other side of the island are for the most part gray and brownish porphyrites (augite-porphyrite?), with some massive beds of coarse agglomerate. Where the scarped slopes of the southwest side of the island were first reached, a bed ten to twenty feet in thickness of a soft pale tuffaceous rock was found. This consists of small fragments and fine amorphous material, all apparently volcanic in origin, and contains embedded pieces of tree-trunks, sometimes more or less silicified, but more usually in the form of lignite. The tuff was observed in some instances to fill what had originally been hollows in the rotten wood. Below this is a bed ten feet or more in thickness of coarse conglomerate with well rounded stones, which also contains lignitized fragments of trees. The pebbles from the conglomerate consist of volcanic rocks similar to those common in the vicinity, and the whole of the water-bedded intercalation appeared to be referable to the temporary

* Voyage of the Vega, vol. II, pp. 280, 291.

occurrence of beach conditions during a stage of the period of volcanic activity to which the rocks of the island generally are due. The dip at this place is southeastward at an average angle of 15° .

In the valley behind Glinka village pretty definite evidences of terracing were observed at several different levels. The horizontal lines are, however, but faintly impressed. The highest of these was estimated to be 600 or 700 feet above the present sealevel.

At Preobajenski, near the northwestern end of the island, the rocks seen were chiefly greenish and purplish porphyritic materials, of which no specimens were brought back. The rocks which form a high cliff to the north of the village at this place were not examined. They are well stratified and dip in a southwestward direction at an angle of about 40° . There is, however, nothing in their appearance to indicate that they differ in origin from the volcanic materials elsewhere characteristic of the island. The native copper from which this island takes its name is found at its northwestern extremity, and specimens of it were given to me by Mr Tillmann, the government officer in charge of the island. Most of these are rounded nuggets and pellets, which had evidently been picked up on the shore; but some of them still include fragments of volcanic rock, gray or reddish, and very probably an agglomerate. A few unworn pieces in the form of sheets or more or less dendritic and crystalline fragments must have been freshly broken from the containing rock.

The occurrence of copper at this place has long been known,* and as early as 1755 the Russian government sent a mining engineer named Jakovlev to report upon it.† It is believed that his report was unfavorable to the value of the deposits.

KAMCHATKA.

Favorable weather enabled a remarkably good general view to be obtained of part of the Kamchatkan coast, in steaming along it from the latitude of Bering island to Avacha bay. Its most striking feature is the series of great volcanic mountains which occur in general parallelism to the axis of the peninsula. Klotchewsky, according to the charts, is over 16,000 feet in height, while Kronotzki, Japounski and Koranski attain 10,608, 9,218 and 11,406 feet respectively. Several of these mountains possess remarkably symmetrical conical forms, unchanged by denudation and indicating continued growth and repair by volcanic forces still near the period of their greatest intensity. Shishaldin and one or two other mountains seen in the Aleutian islands show an approach to

* Account of the Russian Discoveries between Asia and America, Coxe, pp. 123, 206.

† Voyage of the Vega, vol. ii, p. 275.

such regularly conical forms, but taken as a whole the volcanoes of the Aleutian chain, as compared with those of Kamchatka, are but stunted and irregular, the general impression conveyed by such a comparison being that of the much greater age and dwindling condition of vulcanism in the Aleutian region, where the processes of waste have for a long time outstripped those of accretion.

Besides the dominant volcanic cones, covered or heavily striped with snow, there is much irregularly mountainous or hilly country of lower elevation. Very possibly this also may be largely volcanic in origin, but if so it has been denuded and sculptured into ordinary systems of hills and valleys like the mountains of most of the Aleutian islands already described, probably in later Tertiary times.

There is also, along this part of the coast, evidence of a plane of marine denudation. This plane was observed particularly about cape Japounski or Tshipunski, where it gives form to the end of the promontory, and spreads along the bases of the higher hills sometimes with a width of a mile or more. At cape Japounski (estimating from the heights given on the charts) this plane is, in its higher parts, 700 to 800 feet above the present sealevel, but declines gradually to its seaward edge, where it is about 600 feet in height. Traces of the same or a similar plane, though at a somewhat lower level, were again seen in the immediate neighborhood of Avacha bay.

At cape Japounski this flat bordering land or narrow plateau has itself been since cut through by narrow V-shaped valleys which run from the inland hilly tract to the sea.* The excavation of the later valleys seems to have occurred while the land stood some fifty or one hundred feet below its present level, for the valleys are not cut down to the sea, but terminate seaward at such heights above the waterline. The coast cliff may be represented diagrammatically thus:



FIGURE 3.—Diagram illustrating the Profile of the Coast Cliffs at Cape Japounski.

That the plateau of cape Japounski is not one of deposition, but subsequently impressed, is shown by the fact that the underlying rocks are seen in the seacliffs, particularly near the extremity of the cape, to be well stratified and to be inclined at various angles, which are sometimes rather high and are entirely independent of the level contour of the

* The general appearance of cape Japounski is very well illustrated in view no. 3 on chart no. 54, U. S. Hydrographic office.

plane of denudation. These rocks may very probably be similar to those of Petrapavlovsk, but they were not examined.

Diagrammatically the general structure of this part of the Kamchatka peninsula may be represented as ~~above~~, but it must be understood that the illustration is not an actual drawing of any one part of the coast. The order in time of the origin of its several features, as indicated by the form of the land and with reference merely to their relative age, being as follows:

1. Stratified rocks, upturned, and denuded into systems of hills.
2. Prolonged depression of 600 to 800 feet, during which a plane of marine denudation was formed, while the sculpture of the inland hills continued.
3. Elevation of the land to within, say, one hundred feet of its present level, during which narrow valleys were cut out across the plane of marine denudation.
4. Further elevation of the land to about the present level, after which wide delta flats have been formed, as, for instance, that in the bay west of cape Japounski and that about the mouth of the Avacha river. These are so well marked as to indicate a considerable lapse of time.



FIGURE 4.—Diagram illustrating the orographic Characters of the southern Part of Kamchatka.

The towering volcanic cones must, of course, have been formed at a comparatively late date in this history, and their growth has continued up to the present.

Avacha bay, entered by a narrow strait, expands within to a wide body of water from six to ten miles across. The little harbor of Petrapavlovsk is situated on the east side of the bay.

The rocks met with about this harbor are well stratified, often in regular layers a few inches only in thickness. They consist of gray, black and greenish felsites, hard argillites, generally very fine grained, associated with gray, blackish or greenish halleflinta and greenish diabase or chloritic rocks, generally schistose. All these are much indurated and considerably disturbed, sometimes, for limited areas, actually contorted. They are frequently broken by small faults, as well as by innumerable joints, cutting in all directions, so as to shatter easily under the hammer and to form by weathering rubbly slopes. While these rocks are evidently in part composed of ancient volcanic materials, they must have

below

been laid down in water, and date from a period much more remote than that of the existing volcanoes. They closely resemble in lithologic character some of the Paleozoic and Triassic rocks met with in British Columbia, and in their degree of alteration are like to those already noted as occurring on Attu island; but as such characters depend chiefly on the degree and nature of metamorphism to which the beds have been subjected, they afford little clew to the real age of the rocks. No trace of organic remains could be found in them.

In the vicinity of the harbor these rocks have preponderantly southerly dips at rather high angles, and a thickness of several thousand feet of them is here displayed. At the coaling place, near the entrance to the harbor on its west side, they dip south 10° east (magnetic) at an angle of 30° , and similar dips are found along all this side of the harbor. About a mile outside the harbor, on the east shore of Avacha bay, similar rocks are seen in low cliffs, dipping south 40° west (magnetic) at an angle of 60° ; but in following the shore into the harbor varied and irregular dips are met with. Further out, beyond a deep indentation in Avacha bay, the stratification in some of the cliffs appears to be nearly horizontal.

Mr Collie, in the Zoölogy of Captain Beechey's Voyage, notes the occurrence of serpentine as a frequent constituent of the older rocks about Avacha bay. These rocks, as represented in the immediate vicinity of Petrapavlovsk, he refers to in a general manner as clay-slates.*

On the east side of the harbor of Petrapavlovsk, behind the village, a distinct, though faintly impressed line running along the hill, seems to indicate the existence of an old sea-margin at a height of about 250 feet above the present, but apart from this no evidences of terracing were observed at this place. Neither were any erratics or boulder-clay met with; nor were any striated rock-surfaces or other evidences of glaciation anywhere seen. So far as they go, such observations are, of course, entirely negative in character; but it may be affirmed that no traces of the Glacial period, such as those so commonly found on the coast of British Columbia and that of southeastern Alaska, are here apparent.

PRIBILOF ISLANDS.

Mr. J. Stanley-Brown, of the United States Geological Survey, during his residence upon these islands in 1891, made a thorough examination and survey of them. The main results of his work are given in brief in a paper lately read before the Geological Society of America.† Mr

* Zoölogy of Captain Beechey's Voyage, London, 1839, p. 167.

† Bull. Geol. Soc. Am., vol. III, p. 496.

Stanley-Brown found the islands to be entirely volcanic, and for the most part basaltic. The centers of eruption are still recognizable, and the date of origin of the accumulations is regarded as post-Pliocene. No erratics are found upon the higher levels and there are no traces of glaciation either general or local. Raised beaches were not observed, except in one instance which is believed to be due to local volcanic disturbance. The island of Saint George has been considerably affected by orographic movement since its formation, but that of Saint Paul is believed to have remained unchanged.

Though several visits were made to these islands during the summer of 1891, my opportunities for geological observations there were very small as compared with those of Mr Stanley-Brown and the facts noted therefore require the briefest mention only.

The most interesting locality on either island is undoubtedly that of Black bluff, Saint Paul island, where fossils have been collected by Wassressenski, Elliott and others as well as by Mr Stanley-Brown. I had the pleasure of visiting this place with the last named gentleman, and entirely concur with his view as to the mode of occurrence of the fossils, namely, that they are found only in detached fragments of calcareous argillite which are included in a deposit of basaltic scoria and volcanic ash.* The distinctly bedded character of this enclosing rock, however, leads me to believe that it was laid down under water, the products of the volcanic eruption being there mingled with fragments ripped up from the sea-bed by the same force. If this view be correct, it follows that the island, or this part of it at least, has been elevated by an amount of at least 80 feet since the time of the eruption.

The manner in which the fossils occur at this place shows that they cannot be accepted as fixing the precise age of the formation, but only as representing some beds which already existed at that time. Thus the fact that all the molluscs collected here by Mr Stanley-Brown are still living species, while earlier collections included some species now extinct, presents no difficulty.† It tends merely to show that deposits due to the upper Miocene (Astoria group of Dall), with others to which a post-Pliocene date must be attributed, occur in the bed of this part of Bering sea, and to confirm the later post-Pliocene date accorded to eruptions which have produced the islands.

Another fact which seems to show that the island of Saint Paul must have been upraised to some extent since the date of the period of vulcanism is the difference of contour which exists between the higher hills of the island and the sometimes widely extended lower slopes attaching

* Op. cit., p. 497.

† Op. cit., p. 498. Bull. U. S. Geol. Survey, no. 84, pp. 257, 258.

to them. The profile of the southern side of the island as seen from Northeast point may be specially instanced. Here, from the steep slope of Polovina hill, a very gently inclined plain extends seaward to the edge of the low modern seacliffs which now border the actual shore. This flat tract is covered with scoriaceous materials. Its highest part is at an elevation of about 100 feet above the present sealevel, and its existence appeared to me to be most easily explained by supposing that the volcanic ejecta were here distributed and levelled as they fell in a shallow sea. An examination of Mr Stanley-Brown's contoured map of the island* will show that (apart from seacliffs) the slopes below the 100-foot contour line are throughout notably light, while those above it are nearly all much steeper.†

On the low flat land of the Northeast point of Saint Paul island, the bones of whales and walrus are found in considerable abundance imbedded in sandy deposits. These lie at a height of some feet above the highest level of modern storm-wash.

As it is impossible that the remains of whales, at least, could have been carried to their present position otherwise than by the sea (the island having been uninhabited till the time of its discovery by the Russians, about 100 years ago), it appears to be certain that the land has been further raised within quite recent times by an amount sufficient to account for their presence—say, about ten feet. Evidence to the same effect is also found in this vicinity in the wide flat to the west of Hutchinson hill, where the superficial sandy deposits have at some former time been stripped away by the sea, leaving a boulder-strewn tract which is bounded on the inland side by a low step or rise.

In his account of the Pribilof islands (page 499) Mr Stanley-Brown writes as follows :

"There are two fragments of paleontologic evidence connected with these islands which, as they have been used by writers, demand a cautionary word. The tusk of a mammoth was found in the sands of Northeast point on Saint Paul island, and the tooth of one is reported as coming from the shores of Saint George. As there is not a foot of earth upon either island, save that which has resulted from the decomposition of the native rock and the decay of the vegetation, the value of such testimony is questionable."

Dall attributes more importance to these discoveries, and authenticates that on Saint George on the evidence of Veniaminof,‡ while he also quotes Stein as an authority for the occurrence of similar remains on

* Fur-seal Arbitration : Case of the United States, map no. 2.

† It is, however, to be remembered that Mr Stanley-Brown's examination of the island led him to refer the differences here commented on to other causes, which may possibly afford a sufficient explanation of them.

‡ Op. cit., p. 266.

Unalaska island. It will be observed that Mr Stanley-Brown does not question the finding of the mammoth remains on the Pribilof islands, and I do not attach the same significance to the absence of extraneous earthy matter in the soil to which he refers. This, in fact, appears to afford further reason to believe that the bones could not have been carried thither in any adventitious manner, and to render it as nearly as possible certain that the animals to which they belonged must have found their way to the islands at a time when they were connected with the American continent by means of a wide plain, such as Mr Stanley-Brown himself explains in one of the paragraphs of his paper,[†] would be made if an elevation of 200 feet should now take place in Bering sea.

The absence of old sea-margins on the Pribilof islands may be accepted as showing that since the time of their original elevation above the sea they have not been again submerged, but there is no evidence whatever to show that they may not have stood at higher levels.

My observations agree with those of Mr Stanley-Brown in regard to the absence of erratics above the present sea-margin, but it may be added that not infrequent pebbles and small boulders of granitic rocks occur upon the actual beaches in association with local débris. These have in all probability been brought hither either by the floe-ice, which fills this part of Bering sea in winter, or attached to the roots of drift tree-trunks, which are often washed ashore.

NUNIVAK ISLAND.

The form of Nunivak island is very imperfectly represented on the charts. It was approached by us on the 7th of August on its southwestern side, where a landing was effected. On the following day the western and northern shores were coasted at a distance as small as appeared to be compatible with safety, and the next night was spent at anchor in Eteolin harbor, at the northeastern extremity of the island.

The island is throughout grass-covered, but entirely devoid of trees, though a few stunted shrubs are found in some of the valleys. Its coasts are usually rather low, but vertical cliffs of 100 to 150 feet in height appear at the points and projecting headlands, while shelving rocky shores, with occasional sandbeaches and sanddunes, characterize the various open bays. The cliffs show several superposed and horizontal layers of basaltic rock, and in the low hills of the interior of the island similar but overlying massive flows of the same kind may be traced. These hills are all more or less plateau-like in form, and might readily be mistaken in some places for old marine terraces. The highest

[†]Op. cit., p. 496.

parts of the island were estimated at about 500 feet. At Eteolin harbor the rock is a gray olivine-diabase, very porous and cellular, and separated into layers which simulate horizontal bedding, but which are due to flow structure.

Part of the east coast of the island was subsequently seen from a distance, and its appearance is so similar to that of the other coasts that there can be little doubt that the island is entirely composed of nearly horizontal basaltic flows. The basalts examined are all fresh looking and unaltered, like those of Saint Paul island. The much altered sandstones reported by Dall at Eteolin harbor were not found, nor was I able to identify any volcanic cones upon this island.*

No erratics or traces of glaciation were observed on the parts of Nunivak island visited.

CAPE VANCOUVER.

Cape Vancouver, twenty-five miles distant from the eastern coast of Nunivak island, is a projecting point of Nelson island, which is to all intents a portion of the adjacent Alaskan mainland. It is a bold and high promontory, which, though scarcely to be characterized as mountainous, rises to a height of probably 1,000 or 1,500 feet. It evidently forms one of several or many projections of higher land along this part of the Alaskan coast, which are connected by broad, low, level tracts. The north shore of the cape, which alone was examined, forms scarped bluffs or cliffs, rising from the edge of the sea, and presenting fine exposures of sandstones and sandy shales, well bedded and dipping southward, at low and undulating angles. At the extremity of the cape these beds appeared to be horizontal, and on the south side, though imperfectly seen from a distance, they seem to lie at higher and more irregular inclinations.

The sandstones, where examined, are gray, bluish and brownish in color, rather soft, and sometimes nodular. They contain a few very thin and dirty seams of coal or lignite, of which the thickest seen was only a few inches. There are also in the sandstones numerous carbonaceous fragments and occasional fossil leaves, of which a couple were collected. These have been submitted to Sir J. William Dawson, who supplies the following note upon them:

"No. 1. *Juglans acuminata*, R. Braun, Heer, Flora Fossilis Alaskana, 1869, page 38. *Ib.*, Flora Fossilis Arctica, vol. I. *Ib.*, Contributions to Fossil Flora of N. Greenland. Trans. Royal Society, 1869.

"This species is stated by Heer to occur in sandstone at English bay, Alaska. It is also found at Atanekekdruk in Greenland, and is said to occur in the European

* Cf. Dall, op. cit., p. 245.

Miocene at Oeningen and Hohe Blunen. Very similar species, if not mere varietal forms, are credited by Lesquereux and Ward to the Laramie and Tertiary of western America. The plants found with this species at English bay, Alaska, and at Atanekerdluk, Greenland, are closely allied to those of the upper Laramie of Canada, and I have been inclined to refer them to this age rather than to the Miocene.

"No. 2. Fragment of a leaf of considerable size, but too imperfect for determination. It may possibly have belonged to a species of *Quercus* or of a large *Corylus*, like *C. McQuarrii*, but this is quite uncertain."

According to the classification adopted by Dr Dall in his recent work, the beds at cape Vancouver would appear to fall under the Kenai group of the Miocene, though the locality is a new one.*

Upon the beach at cape Vancouver fragments of vesicular basalt are abundant, and the distant outline of the cape led me to suppose that the stratified rocks are capped by basaltic flows in the higher hills a short distance inland from the extremity of the cape.

A fairly distinct though rather narrow terrace of earthy materials was observed along the north shore of the cape at a height of 80 to 100 feet above the sea.

SAINT MATTHEW, HALL AND PINNACLE ISLANDS.

Saint Matthew island, with Hall and Pinnacle islands near it, are situated in the center of the northern part of Bering sea. They are so remote from any other land that they appear never to have been reached by the Eskimo, though polar bears are brought to them on the floe-ice of winter and remain during the summer. Saint Matthew island itself is long and narrow, extending in a northwest by southeast direction for about thirty miles. Hall island, some five miles in greatest length, lies near the northwest end of Saint Matthew, and Pinnacle island is situated at a distance of six or seven miles to the south of the main islands. The islands are very imperfectly delineated on the existing charts.

Saint Matthew island may be described as consisting of the submerged portion of a range of bold rounded hills, some parts of which probably reach an elevation of about 1,500 feet. It is in reality formed of three isolated groups of hills of unequal size which may originally have been separated by narrow straits, but are now united by tracts of low gravelly land washed up by the action of the sea. These low lands include several lagoons, into which streams fall and from which the water percolates through the gravel to the sea. Hall island is in every way similar to Saint Matthew, but happens to be divided from it by a still existing strait.

* Op. cit., p. 234.

The forms of the hills are not rugged or scarped, but they have been cut back into seacliffs of varying height along all the shores.

Effusive { There is no appearance of volcanic craters, cones or centers of eruption, nor were any volcanic rocks of surface origin, such as the basalts of the Pribilof and Nunivak islands, seen about these islands. The hills seem to be the residual portions of much more extensive volcanic accumulations of some antiquity, of which the greater part has been removed by ordinary processes of denudation. So far as examined, they were found to be composed of rocks generally less basic in composition than the basalts and probably in the main of deep seated origin, but nevertheless entirely volcanic or eruptive. No raised beaches or terraces were observed, nor were any recognizable instances of travelled boulders or traces of glaciated rock surfaces seen on the islands of this group.

The following more detailed notes include the results of examinations made on August 10, 11 and 12, 1891:

The cliffs at cape Upright, the eastern end of Saint Matthew island, are in some places about 500 feet in height, very rugged in form and tenanted by numerous seabirds. The sea has here cut back beyond the crests of a small group of hills, so that the ground slopes away steeply inland from the summit of the cliffs. The rocks are everywhere very much shattered and jointed. They consist of greenish and purplish feldspathic materials, often porphyritic, in many cases evidently clastic, and in one place including a hard, pale greenish tuff. These are associated with a gray fragmental rock chiefly composed of granitic material, with much epidote and chlorite. This simulates a granite, but contains also angular fragments of the darker porphyrites. Nearly all these rocks are considerably decomposed, and resemble rocks met with in British Columbia, where the centers of eruption of Miocene date have been cut through or exposed by denudation.

In following the north coast of Saint Matthew island from cape Upright to its deepest indentation, which forms an open bay, where we anchored, a stretch of low land with gravel beach is first passed. Cliffs then border the sea and are composed of rather massive rocks of dark color, resembling those above described. In rounding the most prominent point between cape Upright and the bay, however, a thick stratum of a grayish yellow color is observed in the cliff. This rests with perfect regularity on the darker rocks below, but its upper surface appears to have been plowed up by the passage over it of the overlying material in a molten state. The general dip of the beds is southward at an angle of about 15°. The light colored material is probably tuff or fine volcanic agglomerate.

From the anchorage westward, the rocks of the north shore of Saint Matthew island were seen only from the sea. They appeared to be

similar to those last described, and are very probably of about the same horizon throughout. The pale colored stratum referred to reappears at several places, and always with a low southerly dip away from the sea.

The south side of Saint Matthew island was clearly seen from the sea and closely examined through the telescope westward to about abreast of Pinnacle island. Its general features and the appearance of its rocks are in every way similar to those of the north side.

The general structure of Hall island, in which the same rocks are continued, is illustrated by the subjoined diagram, sketched along its east coast.

The principal dip is here to the northward at low angles, and the rocks consist of a series of "porphyrites," with intercalated tuffaceous and agglomeritic beds. The rocks shown at *a*, *d* and *f* in the diagram, consist preponderantly of grayish purple, purple and gray porphyrites, nearly massive, but sometimes with a rude, irregular, columnar structure, particularly toward the north end of the island, where the rock is distinctly an augite-porphyrity. They have been considerably altered and



FIGURE 5.—Diagrammatic Section along the east Coast of Hall Island.

decomposed, frequently largely silicified by subsequent solfataric action, while they are often markedly rusty in irregular bands. *C* and *e* are pale gray in color, and consist of tuff, volcanic ash or fine agglomerate, which is evidently water-bedded, and in some places rather finely stratified. This is particularly the case in respect to the bed *c*, which is from 200 to 300 feet thick, and is underlain by a similar thickness (*b*) of coarse brownish and blackish agglomerate, holding some fragments from one to three yards in diameter.

The section evidently represents the results of volcanic action which has been in part or altogether submarine. The rocks are everywhere much fractured and jointed, giving rise under the action of the sea to bold, rugged and picturesque cliffs like those of cape Upright. Much chalcodony and jasper occur on the east side of Hall island near its southern end in the porphyritic rocks, and these minerals here compose a considerable portion of the worn beach pebbles in some places. The chalcodony is generally white or milky, the jasper red or red veined with yellow.

In 1791 Sauer, of Billing's Russian Scientific Expedition, landed on

this island, probably near this place, and particularly notes the abundance of jasper and chalcedony.*

Pinnacle island was so named by Cook in 1778. It is a narrow crest of jagged rocks, apparently about a mile in length and lying north and south. On some charts its height is given at 900 feet, and its higher parts may reach this elevation, but as its form is very imperfectly shown on the charts no accuracy can be attached to the height stated. It presents a series of vertical and sometimes overhanging cliffs to the sea on both sides, gashed by transverse breaks into a series of narrow peaks and pinnacles. In many places the sea washes the base of sheer cliffs which often show low caves along the water line. Elsewhere rough narrow beaches permit a landing to be made in calm weather.

Myriads of birds find nesting places in the cliffs. Several polar bears were also observed on the island, and on a low neighboring rock to the southeast a considerable colony of sealions was noticed.

Some hours were spent about the island under favorable circumstances of weather on August 12, and the shore was closely followed all round in the steam launch of H. M. S. *Pheasant*.

The rocks are everywhere very similar to those of cape Upright, and evidently belong throughout to the same old volcanic series.† Like these, they are very much shattered and disturbed. Dark purplish and greenish feldspathic rocks, which are often distinctly stratified or strati-form and dip at various angles, are perhaps the most abundant. Some beds of gray arkose material, like that of cape Upright, were also seen here. These are now consolidated into a hard rock, but occasionally show very distinct stratification. The granitic débris is here embedded in a chloritic matrix.

SAINT LAWRENCE ISLAND.

Saint Lawrence island, the largest in Bering sea, is about 85 miles in length, and is situated not far to the south of Bering strait. The western end of this island was coasted from Southwest point to cape Chibukak. Between Southwest point and cape Sanachno the shore is formed by rugged cliffs several hundred feet in height, with some outlying rocks and reefs. These cliffs are composed for the most part of a gray rock, which from its massive appearance, as well as from the observations subsequently made at cape Chibukak, is almost certainly granitic. This is seen to be overlain, where higher ground approaches the shores, by hori-

* An Account of a Geographical and Astronomical Expedition to the northern Parts of Russia. London, 1802 p. 235.

† The statement that Pinnacle island is a "volcanic chimney, still smoking" is incorrect. Bull. U. S. Geol. Survey, no. 84, p. 258.

zontal or very lightly inclined stratified materials of brownish and reddish brown colors, which are with little doubt volcanic, but more probably scoriaceous or agglomeritic than basaltic. Low plateau-like hills some miles further inland appear to be composed of similar materials. Higher hills, at a greater distance from this part of the shore, were seen only very imperfectly, between clouds.

The northeast point of the island, ending in cape Chibukak, consists of a plateau about 200 feet in height, with a notably level outline as seen from the sea. This plateau, however, declines to the southward to lower land, by which it is connected with the rest of the island. It breaks

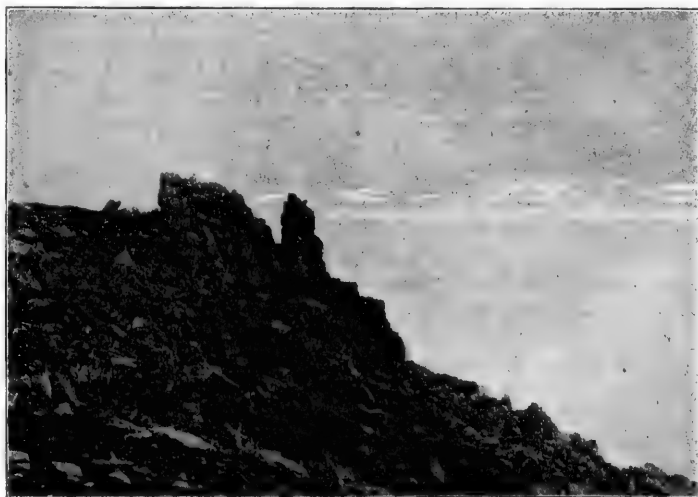


FIGURE 6.—Shattered granitic Rocks, Cape Chibukak, Saint Lawrence Island.

off to seaward in cliffs or steep rocky slopes, with here and there projecting pinnacles of fissured rock rising from them.

A landing was made on the east side of cape Chibukak, where the plateau was found to consist of gray biotite-granite of uniform color and texture and moderately coarse grain. The surface of the plateau is everywhere covered with irregular, angular, broken blocks of granite, much like those often found on high mountain summits, and doubtless the result of severe climatic conditions acting upon the naturally jointed rocks. No erratics were found upon the plateau nor any traces of glacial striation or smoothing, though if such at any time existed they may

have been lost in consequence of the breaking up of the original rocky surface. The impression conveyed was, however, that this condition of the surface was of ancient date and had been preserved because of the exemption of the region from the effect of glaciating agents. Some stones were found on the present beach which did not appear to belong to the actual vicinity, but if transported from any distance the abundance of floe-ice known to occur in these seas in winter is quite sufficient to account for this. Nothing whatever was found to favor the theory of an "oversweeping glacier," the supposed action of which has been particularly illustrated by Mr John Muir from the contours of hills and cliffs on this island.*

The level contour of the plateau suggests that it may represent an ancient plane of marine denudation or peneplain. On the east side of the cape a fairly distinct terrace occurs at a height of about fifty feet above the sea. This has been cut back in the granitic rocks as a narrow step, which is now encumbered with broken blocks from the old sea-cliff above.

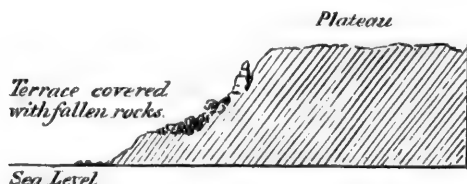


FIGURE 7.—Diagrammatic Section of the east Side of Cape Chibukak, Saint Lawrence Island.

Views of the island as a whole, from cape Chibukuk, and also from the sea to the westward with a remarkably clear atmosphere, failed to disclose any distinct volcanic cones or craters, but as both Captain Hooper and Mr Muir speak very positively of the existence of such cones on the island, it is probable that they are to be found in its central or eastern parts.†

The surface of the island, so far as seen, consists wholly of barren moorland, with grass and moss and often rock. There are no trees, and large masses of snow were found in some places along the bases of the cliffs and down to the level of the sea.

PLOVER BAY.

From Saint Lawrence island we crossed to the Siberian coast at Plover bay, so named because *H. M. S. Plover*, Captain Moore, wintered there

* Report of the cruise of the *Corwin*, 1881, pp. 137-140.

† *Ibid.*, pp. 33, 140.

in 1848-'49, in connection with the Franklin search. It is situated in latitude $64^{\circ} 30'$, and indents the southern part of the promontory separating Anadir bay from Bering strait. The weather was such as to give us while approaching it a good view of a long stretch of this part of the Siberian coast. The outlines of this coast are everywhere bold and mountainous, though none of the highest points in sight probably exceed 4,000 feet in elevation. It is entirely bare and treeless, brownish or gray, showing only here and there in the valleys the green color of herbage.

Fiord-like inlets, and narrow straits of the same nature, characterize this part of the coast, but they are on a small scale as compared with those of British Columbia and southeastern Alaska. Soundings given on the charts show that the water in these inlets and channels is deeper than that about their mouths, but the greatest depth actually recorded appears to be about 50 fathoms.*

Plover bay is one of these small fiords, surrounded by steep, rocky mountains, notably covered everywhere on their slopes with talus material, consisting of broken angular rock, through which spires and crags of solid rock often project, especially on the sides facing the sea. Generally speaking, the mountains show ordinary denudation forms, with wide buttress-like projections and intervening steep valleys and ravines; the shapes assumed resembling those commonly met with where the rocks are so much shattered and jointed as to crumble away under the weather with almost equal facility in any direction. The ranges end along the coast in capes terminated by seacliffs. On the whole, the most peculiar feature is the great abundance of loose angular material. It is doubtful to what extent this may be directly referred to rapid disintegration due to the subarctic climate of the climate, or in how far it may be accepted as evidence of prolonged weathering uninterrupted by glaciating agents.

From cape Tchalpin (Indian point) to cape Nismenni, and thence as far as cape Tchukotski, the rocks as seen from the sea are generally gray in color and are in all probability granitic. Between the range ending seaward at cape Tchukotski and the valley containing lake Moore of the chart is a smaller range composed near the sea of similar gray rocks, but about two miles inland assuming brownish and reddish colors. Brownish and reddish weathering rocks also compose most of the next range, which separates lake Moore from Plover bay and includes mount Slavianska. From what was afterward seen in Plover bay, this difference of coloration may not indicate any essential change in composition.

* Dall, however, speaks of a depth of over 100 fathoms having been obtained in the center of Plover bay. *Alaska and its Resources*, pp. 466, 512.

Bold Head, which forms the seaward end of the range last referred to, shows in its cliffs several well marked intrusive dikes, weathering yellowish and blackish.

The whole west side of Plover bay, as well as the outer coast beyond it for several miles, consists of gray rocks which are likewise probably granitic.

The only locality in which the rocks were actually examined in this region, in the short time available, was the east side of Plover bay between port Providence and Emma harbor. They are here, in the main, rather coarse grained, gray biotite-granite, much like that of the west end of Saint Lawrence island, but in places passing into a hornblende granite. There is also, however, a considerable proportion of gray and reddish porphyritic rock, resembling a mica-syenite or minette, which is probably later in date than the granite and intrusive in it. No strictly volcanic rocks of any kind were seen in this vicinity, nor were any stratified rocks observed.

The general description of this part of the Siberian coast above given will show that superficial earthy deposits are not abundant, but there are in the vicinity of Plover bay some deposits of this kind which attracted special attention.

The point on the outer coast immediately east of the valley of lake Moore, terminates in an apron-like flat of land which breaks off seaward in a low cliff, apparently formed of hard clay, weathering to a fawn-color and thickly studded with large boulders which lie more or less definitely in regular lines, giving a stratified appearance to the whole. Material of the same kind is preserved in the angle of the next bay nearest to Bold Head. It was also seen from a distance to form the coast along the bottom of the bay into which Reindeer river flows, on the opposite side of the entrance of Plover bay, and again occurs in two places on Emma harbor on the west side, a little within the entrance to the harbor and at its southern bay.

The last named locality was the only one actually examined on the ground. The deposit is here bluish gray where freshly exposed, and is a rather hard clay with a considerable proportion of coarse sand and gravel, containing many boulders of somewhat varied lithologic character. These are subangular in form, but none were found which actually showed glacial scratching, neither were any shells found in the mass. The deposit, nevertheless, undoubtedly represents a species of boulder-clay. It does not anywhere take the form of definite terraces, but as it is nowhere seen, or at least not in any considerable mass, at a greater height than about 200 feet above the sea, while it is occasionally rather wide spread below this level, it may be assumed as a whole to

represent an approximate terrace-level, having relation to a former depression of the land of about the amount stated.

In Plover bay, on August 16, large masses of snow occupied many of the hollows, sometimes quite down to the edge of the sea. Portions of these accumulations undoubtedly last throughout the summer. No glaciated rock surfaces were actually observed, but this negative evidence is here of small value, as it depends upon observations made in a very short time and over a very small area. Mr Muir speaks of having found glaciated rock surfaces in Plover bay, and pictures it as having been at one time filled by a glacier thirty miles in length and from 2,000 to 3,000 feet in thickness.*

GENERAL REMARKS.

Bering sea is a dependency of the north Pacific, marked off from it by a bordering chain of islands like those which outline Okhotsk sea and the sea of Japan. It differs from these two seas by reason of its connection to the north with the Arctic ocean, and in the fact that while the whole eastern part of its extent is comparatively shallow, the profounder depths of the north Pacific (in continuation of the Tuscarora deep) are continued into its western part. The Aleutian islands, regarded as a line of demarkation between the main ocean and Bering sea, are analogous to the Kurile islands with Kamchatka, and to the islands of Japan. As to the Commander islands, though these appear to lie in the continuation of the arc formed by the Aleutians, they are separated by a wide and, so far as known, very deep stretch of ocean from the last of these islands, and it is wholly probable that they may represent an altogether independent local elevation analogous to that to which Saint Matthew and its adjacent islands are due.

The western part of Bering sea has as yet been very imperfectly explored with the deep-sea lead, but the following general facts may be gathered from the existing charts: The entire chain of the Aleutian islands is bordered at no great distance to the south by abyssal depths of the Pacific. The whole western portion of the chain likewise slopes rapidly down on the northern side into very deep water, exceeding 1,000 fathoms as far to the eastward as Unimak island; but from the vicinity of Unimak pass (longitude 165° west) the depths to the north of the islands are consistently less than 100 fathoms. Beginning near the Unimak pass, the edge of the hundred-fathom bank runs northwestward, passing to the west of the Pribilofs and Saint Matthew island and meeting the Asiatic coast in the vicinity of cape Navarin, in about north latitude 60°. Thus all parts of Bering sea to the north and east of this line, together

* Report of the Cruise of the Corwin, 1881, p. 143.

with Bering straits and much of the Arctic ocean beyond, must be considered physiographically as belonging to the continental plateau region and as distinct from that of the ocean basin proper, and there is every reason to suppose that it has in later geologic times more than once and perhaps during prolonged periods existed as a wide terrestrial plain connecting North America with Asia.

In all probability this portion of the continental plateau is a feature much more ancient than the mountain range of which the outstanding parts now form the Aleutian islands. This range, though to some extent due to uplift, as for instance in the case of Attu island, is chiefly built up of volcanic materials. Its eastern part, in the Alaskan peninsula and as far as the Unimak pass, must be regarded as having been built upon the edge of the old continental plateau. Its western part, though certainly the continuation of the same line of vulcanism, runs off the edge of the plateau and rises directly from the ocean-bed.

The available evidence goes to show that the submarine plateau of the eastern part of Bering sea, together with much of the flat land of western Alaska, was covered by a shallow sea during at least the later part of the Miocene period, while the most recent period at which this plateau stood out as land is probably that at which, according to facts previously noted, the mammoth reached the Pribilof islands and Unalaska island across it.

As to the date of the formation of the Aleutian chain, Dall inclines to the belief that it marks a line of weakness or faulting which has been in course of development since early Mesozoic times.* This may be the case, but I have found nothing on record nor have I myself met with any facts which appear to require so early a date of origin. The association of the volcanic materials of the islands in some cases with Miocene marine fossils and with plant-remains, noted by Dall, shows that early in that period, or possibly before it, the islands existed in some form, for the organic remains are those of shores and shallow water, not of the deep sea. The existence of very ancient volcanic products forming well bedded rocks on Attu island, and perhaps elsewhere in its vicinity, does not appear to have any necessary connection with the date of the vulcanism to which the islands as a whole are referable, for such rocks are very common in formations of many periods on both sides of the Pacific, and may be due to volcanic action along lines entirely distinct from that now occupied by the Aleutians and long since extinct. We may therefore, I believe, assume that the building of the Aleutian islands began in the later Eocene or earlier Miocene, that it was continued with vigor throughout the Miocene, and in an intermittent and declining way has survived up to the present time.

* *Op. cit.*, p. 242.

The evident marks of prolonged subaërial denudation which exist on all the islands of this chain which I have seen, appear further to show that it has been long exposed to such action since the main period of its formation; that as a rule it has stood unsubmerged since the Miocene, and that though it may at some period have been more elevated, it has either not been more deeply submerged than it is at present, as, if so, that such submergence has endured for a comparatively very brief period.

Saint Matthew and its adjacent islands, with the Commander islands, appear to have much the same history with the Aleutians, and may very well have been coeval with them in origin. The later eruptions, to which the Pribilof islands and Nunivak island are due, have doubtless also left their traces in the Aleutian chain, while the volcanoes of Kamchatka may have originated at this later period and have continued their activity with little relaxation to the present time.

The planes of marine denudation, noted particularly at Saint Lawrence island and at cape Japounski, on or near the western border of Bering sea, seem to require prolonged stability at a level some hundreds of feet lower than the present in that part of the region, and the fact that this plane appears to be capped by volcanic rocks at Saint Lawrence island (particularly if no evidence of existing volcanoes is found there), makes the date of this submergence somewhat remote. It may be conjectured that it corresponds with the general submergence of the later Miocene. That the amount of such submergence should vary in different localities is quite in accord with what might be expected, perhaps, in any region, certainly in one in which volcanic forces of a local kind have to be allowed for.

The difference of climate which would result in the northwestern part of North America from the closing of Bering strait and the addition of the shallow eastern part of Bering sea to the continental land may not have been very great, inasmuch as the strait is even now a shallow one and no very great volume of abnormally cold or warm water flows through it in either direction. The effect would be to slightly lower the temperature and decrease the precipitation on the adjacent lands. Evidence has, however, recently been obtained of a much more important factor in regard to late changes of climate in this region, in the observations of Mr I. C. Russell, which show that the great mountain range of the Saint Elias alps must have been entirely formed in Pliocene or post-Pliocene times.* The crumpling and upheaval of the beds which now form this range must have relieved a notable and accumulating tangential pressure of the earth's crust, the result of which it is yet difficult to trace; but that it must have brought about extensive changes of level

* National Geographic Magazine, Washington, p. 174. Bull. U. S. Geol. Surv., no. 84, p. 259.

throughout the region over which this pressure was exerted seems certain, and I am inclined to suppose that it may have had much to do with the great later Pliocene uplift and subsequent depression to which the British Columbian region appears to have been subjected.*

One of the most remarkable features connected with the Bering sea region is the entire absence of any traces of a general glaciation. Statements to the effect that Alaska, as a whole, showed no such traces were early made by Dall † and concurred in by Whitney. The result of my later investigations in British Columbia and along the adjacent coasts have been to show that such original statements were altogether too wide; that a great Cordilleran glacier did exist in the western part of the continent, but that it formed no part of any hypothetical polar ice-cap, and that large portions of northwest America lay beyond its borders.‡

Statements made by Mr John Muir, in which he not only attributed every physical feature noted by him in Bering sea to the action of glaciation, but even expressed the opinion that Bering sea and strait represented a hollow produced by glaciation,§ remain altogether unsupported. It might be unnecessary even to refer to them but for the fact that they relate to a region for which the data on this subject from other sources are so small. No traces have been found of general glaciation by land ice in the region surrounding Bering sea, while the absence of erratics above the actual sealine show that it was never submerged for any length of time below ice-encumbered waters.

These facts, moreover, connect themselves with similar ones relating to the northern parts of Siberia in a manner which will be at once obvious to any student of the glacial period.

Respecting the latest changes in elevation of the land, it may be stated that in several widely separated places there is evidence of a recent slight general uplift. This was noted at Unalaska, Attu, Bering island, Saint Paul island and Saint Matthew island, but the amount of elevation indicated is small, being in fact from 10 to 30 feet only.

* Trans. Royal Soc. Canada, vol. vii, sec. iv, p. 54.

† Alaska Coast Pilot, 1869, pp. 195, 196; Alaska and its Resources, pp. 460, 461.

‡ Quart. Journ. Geol. Soc., vol. xxxiv, p. 119; vol. xxxvii, p. 283; Report of Progress, Geol. Surv. Can., 1877-78, pp. 136 B, 151 B; Trans. Royal Soc. Canada, vol. vii, sec. iv, plate ii, map 4.

§ Report of the Cruise of the Corwin, 1881, p. 147.

ems cer-
ch to do
o which

ring sea
State-
ces were
t of my
t coasts
oo wide;
the con-
cap, and

s.†
tributed
of glacia-
it repre-
ported.
hat they
sources
by land
erratics
y length

lating to
obvious

be stated
ent slight
nd, Saint
ion indi-